Epidemiological studies of Schistosoma mattheei infections in cattle in the highveld and lowveld communal grazing areas of Zimbabwe

Pfukenyi, D.M.; Mukaratirwa, S.; Willingham, Arve Lee; Monrad, Jesper

Published in:
Onderstepoort Journal of Veterinary Research

DOI:
10.4102/ojvr.v73i3.144

Publication date:
2006

Document version
Publisher's PDF, also known as Version of record

Epidemiological studies of *Schistosoma mattheei* infections in cattle in the highveld and lowveld communal grazing areas of Zimbabwe

D.M. PFUKENYI[1]*, S. MUKARATIRWA[2], A.L. WILLINGHAM[3] and J. MONRAD[3]

ABSTRACT

PFUKENYI, D.M., MUKARATIRWA, S., WILLINGHAM, A.L. & MONRAD, J. 2006. Epidemiological studies of *Schistosoma mattheei* infections in cattle in the highveld and lowveld communal grazing areas of Zimbabwe. *Onderstepoort Journal of Veterinary Research*, 73:179–191

During the period between January 1999 and December 2000, the distribution and seasonal patterns of *Schistosoma mattheei* infections in cattle in the highveld and lowveld communal grazing areas of Zimbabwe were determined through monthly coprological examination. Faecal samples of cattle were collected from 12 and nine dipping sites in the highveld and lowveld communal grazing areas, respectively. Patterns of distribution and seasonal fluctuations of the intermediate host-snail populations and the climatic factors influencing the distribution were also determined at monthly intervals from November 1998 to October 2000, a period of 24 months, in six dams and six streams in the highveld and nine dams in the lowveld communal grazing areas. Monthly, each site was sampled for relative snail density, the vegetation cover and type, and physical and chemical properties of the water. Mean monthly rainfall and temperature were recorded. Snails collected at the same time were individually examined for shedding of cercariae of *S. mattheei* and *Schistosoma haematobium*. A total of 16264 (5418 calves, 5461 weaners and 5385 adults) faecal samples were collected during the entire period of study and 734 (4.5%) were positive for *S. mattheei* eggs. Significantly higher prevalences were found in the highveld compared to the lowveld ($P<0.001$), calves compared to adult cattle ($P < 0.01$) and the wet season compared to the dry season ($P<0.01$). Faecal egg output peaked from October/November to March/April for both years of the study. *Bulinus globosus*, the snail intermediate host of *S. mattheei* was recorded from the study sites with the highveld having a significantly higher abundance of the snails than the lowveld ($P<0.01$). Monthly densities of *B. globosus* did not show a clear-cut pattern although there were peaks between March/May and September/November. The mean number of snails collected was positively correlated with the water plants *Nymphaea caerulea* and *Typha* species. Overall, 2.5% of *B. globosus* were shedding *Schistosoma* cercariae. In the highveld, 2.8% of *B. globosus* were infected with schistosome cercariae and 1.5% in the lowveld, with the figures at individual sites ranging from 0–18.8% in the highveld and from 0–4.5% in the lowveld. The cercariae recorded here were a mixture of *S. mattheei* and *S. haematobium* since they share the same intermediate host. The transmission of *Schistosoma* cercariae exhibited a marked seasonal pattern, being more intensive during the hot, dry season (September/November).

Keywords: Cattle, communal grazing, epidemiology, *Schistosoma mattheei*, Zimbabwe

* Author to whom correspondence is to be directed. E-mail: dmpfukenyi@yahoo.com

[1] Department of Clinical Veterinary Studies, Faculty of Veterinary Science, University of Zimbabwe, P.O. Box MP167, Mt Pleasant, Harare, Zimbabwe

[2] Department of Paraclinical Veterinary Studies, Faculty of Veterinary Science, University of Zimbabwe, P.O. Box MP167, Mt Pleasant, Harare, Zimbabwe

[3] Danish Centre for Experimental Parasitology, Dyrlaegevej 100, DK-1870, Frederiksberg C, Copenhagen, Denmark

Accepted for publication 5 April 2006—Editor

INTRODUCTION

Schistosoma mattheei is the only schistosome present in cattle in Zimbabwe (Lawrence 1978). A survey of the species of snails transmitting schistosomes in Zimbabwe has been reported by Makura & Kristensen (1991) and reviewed by Mukaratirwa & Kristensen (1995). Natural infection of snails in Zimbabwe with *S. mattheei* has only been recorded in *Bulinus globosus* (Shiff, Coutts, Yiannakis & Holmes 1979; Chandiwana, Christensen & Frandsen 1987). The prevalence of *S. mattheei* infection in cattle in Zimbabwe has been reported by Lawrence (1978). Condy (1960) found the parasites in 69.15 % of 2 509 cattle slaughtered at three abattoirs, the prevalence varying from 35–95 %. The prevalence of *S. mattheei* as determined by coprological examination was 3.1 % in Chiweshe communal farming areas (Vassilev 1994) and 4.9 % in Mashonaland East Province of Zimbabwe (Vassilev 1999).

Studies on the prevalence of *Schistosoma* infection in cattle in Zimbabwe have mainly been concentrated in the highveld of Zimbabwe (Vassilev 1994, 1999). Little information is available on the life cycle and transmission dynamics of the host-parasite systems. In order to obtain information on the life cycle and transmission dynamics of *Schistosoma* infection in cattle, a longitudinal study was carried out in the highveld and lowveld communal grazing areas of Zimbabwe from January 1999 to December 2000.

MATERIALS AND METHODS

Study location

Based mainly on rainfall and temperature, Zimbabwe is divided into agro-ecological regions I–V (Fig. 1). Based on the altitude, the country is divided into three major relief regions, namely the highveld (1 200–2 000 m), middleveld (900–1 200 m) and the lowveld (below 900 m).

The rainy season is from November/December to March/April, and the dry season occurs from May to

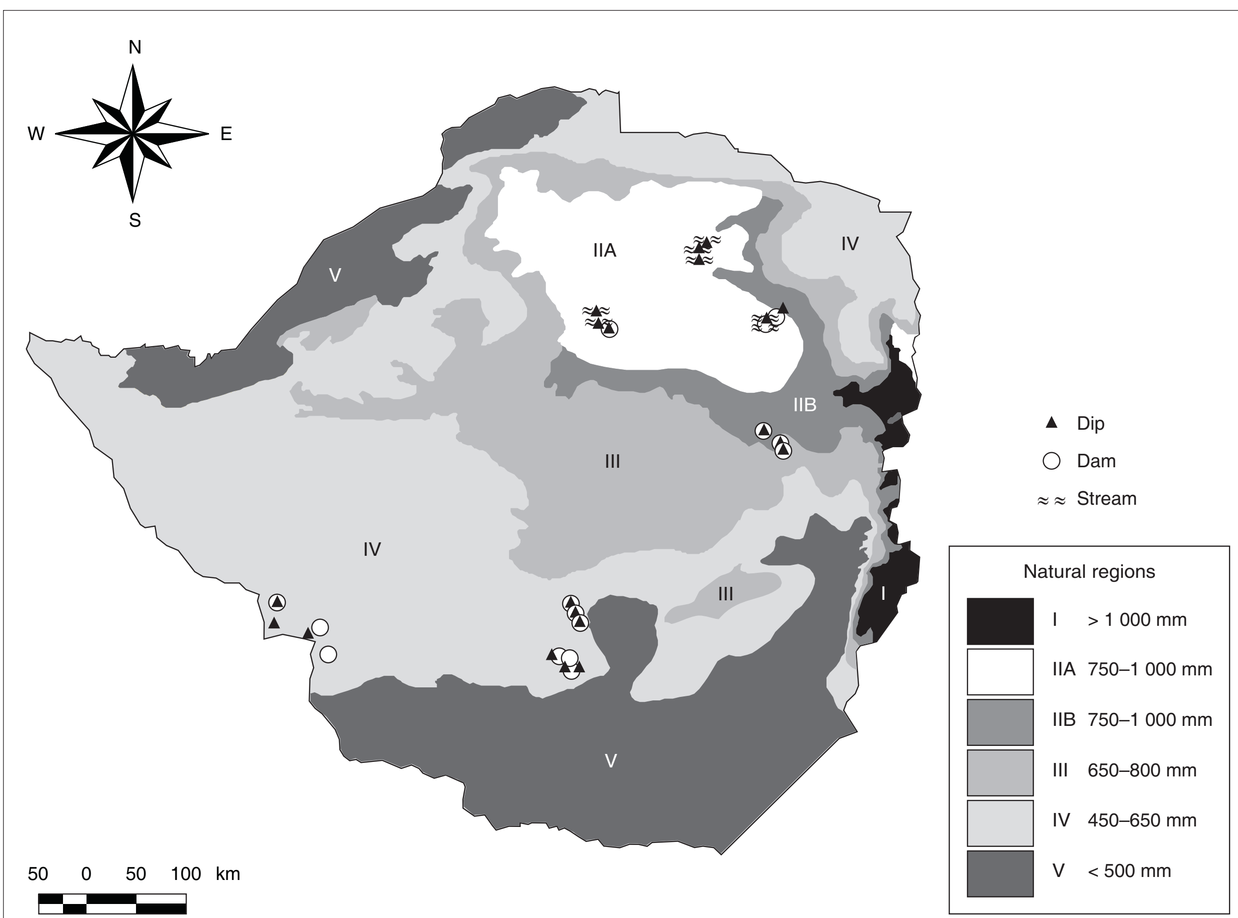


FIG. 1 Location of dipping tanks and snail habitats sampled in the different natural regions in the highveld and lowveld communal grazing areas of Zimbabwe

TABLE 1 Study sites, cattle census and total samples collected in the highveld and lowveld communal grazing areas of Zimbabwe for the period January 1999 to December 2000

Region	District	Distance from nearest meteorological station (km)	Number of dip tanks surveyed	Cattle census	Total faecal samples collected	Number of dams surveyed	Number of streams surveyed
Lowveld	Zvishavane	12	3	20 175	2 116	3	0
	Mberengwa	14	3	30 649	3 174	3	0
	Plumtree	9	3	24 041	2 504	3	0
Highveld	Wedza	8	3	30 189	3 121	3	0
	Murewa	10	3	25 801	1 390	2	1
	Zvimba	13	3	12 339	1 242	1	2
	Mazowe	10	3	26 165	2 716	0	3

October. The respective mean annual rainfall for the different Regions is shown in Fig. 1. Regions IV and V receive low and erratic rainfall, and are subject to periodic droughts.

Hills and valleys characterize the topography of the highveld, in which streams and rivers are located. Man-made dams, rivers, streams and marshy areas, which serve as watering places for livestock, are common in the highveld. In the lowveld, the topography is generally flat with man-made dams serving as watering points for livestock.

Seven districts were randomly selected, four from agro-ecological region III (highveld) and three from region IV (lowveld) (Fig. 1 and Table 1).

Selection of study sites

Dip tanks were chosen as the study sites because of the availability of handling facilities for and access to larger populations of cattle. Three dip tanks were randomly selected from each district giving a total of 21 study sites—12 from the highveld and nine from the lowveld (Table 1). In these areas, cattle were dipped weekly during the rainy season and fortnightly during the dry season for the control of ticks.

Study animals

Local indigenous Sanga type cattle were used in the study. These are a stabilized *Bos taurus* x *Bos indicus* cross breed, commonly known as "Mashona". Cattle from each of the study sites were categorized into calves (less than 12 months old), weaners (1–2 years old) and adults (over 2 years old). Calves and weaners were further divided into males and females, adults into oxen and bulls, and dry, lactating and pregnant cows. Rectal faecal samples were collected from each category once every month. The survey covered the period from January 1999 to December 2000.

Snail studies

In each of the study districts, both drinking and grazing sites that represented habitats of the intermediate host snails were identified (Fig. 1). These habitats included streams and man-made dams used as drinking sites for cattle, and human contact sites for recreational (fishing and swimming), domestic (bathing and laundry) and agricultural (irrigation) purposes.

From November 1998 to October 2000 each site was sampled at monthly intervals for snails, using the scooping method as described by Coulibaly & Madsen (1990). However, due to logistical problems, no snails could be collected from some of the sites in March, April, June and August 2000. Each snail collected was identified using the description of Brown & Kristensen (1989). To establish the seasonal breeding trends of the snails, the shell height of each was measured before it was returned to its habitat. The snails were grouped into juveniles (4–5 mm) and adults (> 5 mm) only as the sampling method used precluded the collection of snails less than 4 mm in length.

All snails sampled at each site were screened for patent *Schistosoma* spp. infection by placing them in individual glass tubes and exposing them to fluorescent light for 1 h, followed by darkness for another hour. Emerging cercariae were identified using the key of Frandsen & Christensen (1984) and the percentage of snails infected with *Schistosoma* cercariae was calculated monthly for each site. However, electrophoretic analysis was not done to distinguish infections of *S. mattheei* from those of *Schistosoma haematobium*.

Aquatic vegetation from the snail habitats, the electrical conductivity and pH of the water were recorded monthly for each site. Electrical conductivity and pH were both measured at the study sites using a portable electronic conductivity meter (Phillips Heriss, 20.1267) and a portable pH meter (Phillips Heriss, 20.1264).

Parasitological analysis

Faecal samples were quantitatively examined for *S. mattheei* eggs using the sedimentation technique described by Boray & Pearson (1960). Spindle-shaped eggs with a terminal spine were considered to be those of *S. mattheei* as no other schistosome species infecting cattle have been reported in the country. The use of ecological terms is in accordance with the definitions of Margolis, Esch, Holmes, Kuris & Schad (1982).

Meteorological data

Mean monthly temperatures and mean monthly rainfall data from the meteorological station nearest to each site were obtained from the recordings by the Department of Meteorology, Belvedere, Harare.

Statistical analysis

Faecal egg counts were logarithm-transformed [$\log_{10}$ (egg count + 1)] to stabilize the variance before analysis. The effect of age, sex, year, season and location on logarithm-transformed egg counts was measured by the General Linear Model (GLM) in SPSS (version 8.0). Categories were generated as follows: three for age (calves < 12 months old, weaners 1–2 years old and adults > 2 years old), two for season (wet [November to April] and dry [May to October); nine for sex (female calves, male calves, female weaners, male weaners, dry, lactating and pregnant cows, oxen and bulls) and two for location (highveld and lowveld). The Least Significant Difference was used as the post-hoc test to measure variances between different categories. Values of $P <$ 0.05 were considered as significant. The correlation between egg counts and climatic factors (rainfall and temperature) was determined by linear regression model.

To stabilize for variances, the snail counts were logarithm-transformed [$\log_{10}$ (snail count + 1)]. The effect of location, season, year and type of habitat on transformed snail counts, as measured by GLM and least significant difference was used as the post-hoc test to measure variances between different categories. For seasonal analysis of fluctuations in snail populations, the year was divided into four seasons; rainy (December to February), post-rainy (March to May), cold dry (June to August) and hot dry (September to November) as described by Chandiwana *et al.* (1987). The correlation between snail densities and rainfall and temperature was analyzed using a linear regression model.

RESULTS

Faecal egg counts

Faecal samples of total of 16 264 (5 418 calves, 5 461 weaners and 5 385 adults) were collected during the study period and 734 (4.5 %) of the samples were positive for *S. mattheei* eggs. In both regions the percentage of animals positive for *S. mattheei* eggs differed significantly between the 2 years, with the second year having a significantly higher prevalence ($P < 0.01$) than the first year (Table 2). During both years the highveld had a significantly higher prevalence ($P < 0.001$) than the lowveld (Table 2) and calves had a significantly higher prevalence ($P < 0.001$) than the weaners and adults in both regions (Table 2). Except for female calves on the highveld in Year 2, there were no significant differences between female and male calves and between female and male weaners (Table 2)

The highest recorded monthly egg count during the study period was 150 eggs per gram (epg) of faeces in a calf in December 1999. The mean faecal egg count for combined positive animals was 26.7 and 15.8 in the highveld and lowveld, respectively. Calves, weaners and adults had mean faecal egg counts of 31.6, 19.0 and 12.3 epg of faeces, respectively.

For both regions and years, the wet season had a significantly higher prevalence of schistosome eggs and the mean egg counts were also higher ($P <$ 0.001) than the dry season (Table 3).

Faecal egg output was persistent during all months of the 2-year period of study. All age groups showed a similar seasonal trend with respect to both prevalence and mean faecal egg counts. Random calving occurs in communal grazing areas, and thus the age groups were combined as shown in Fig. 2. Mean monthly faecal egg output and monthly prevalences of *S. mattheei* were significantly higher in the highveld than the lowveld ($P < 0.01$) (Fig. 2). Overall, mean monthly faecal egg counts and prevalences peaked from October/November to March/April (Fig. 2).

TABLE 2 Mean prevalence (%) of *Schistosoma mattheei* in the different categories of cattle by year, region and district in the highveld and lowveld communal grazing areas of Zimbabwe as from January 1999 to December 2000

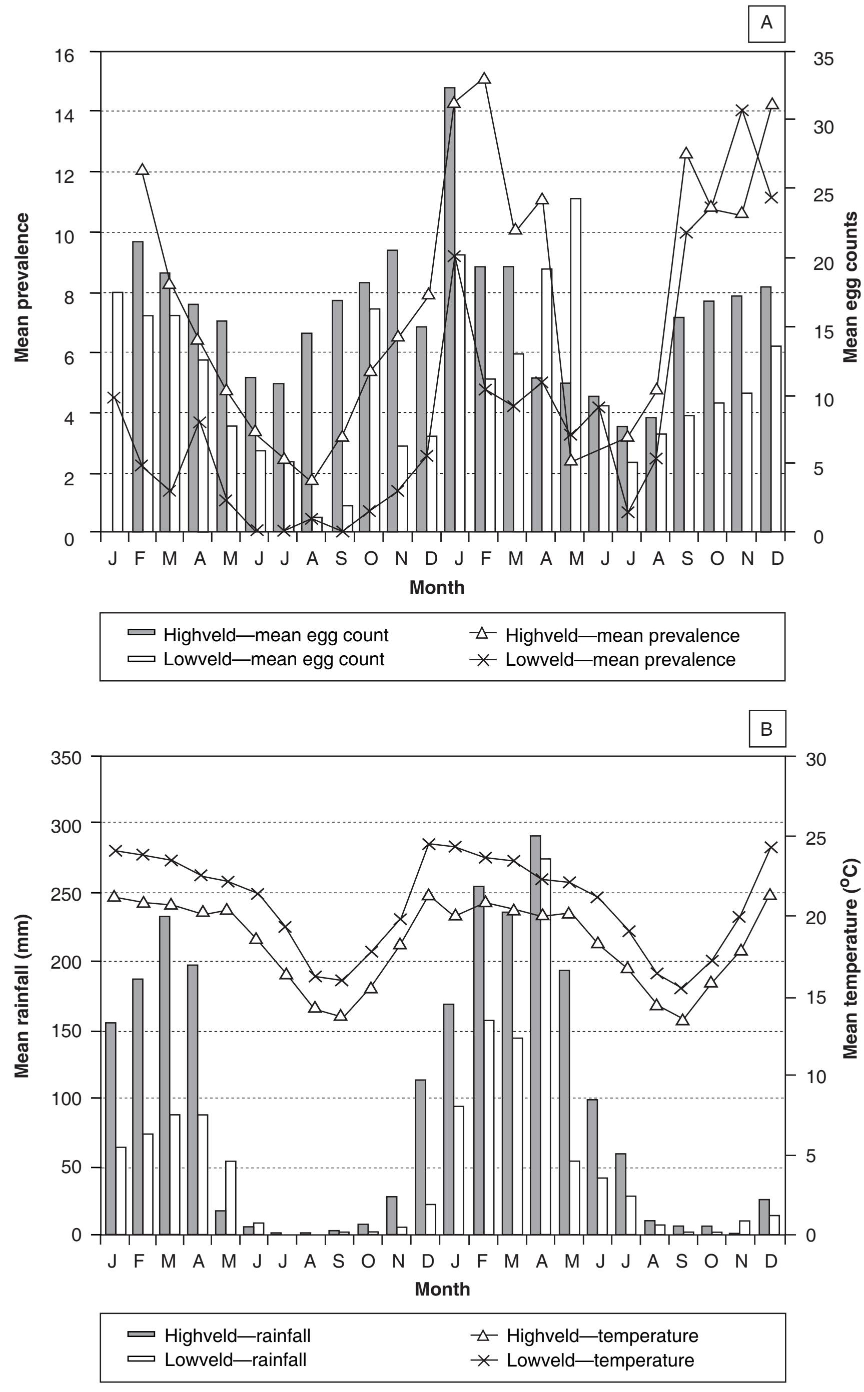
Year	Region	Agro-ecological zone	District	*N	Animal category									Overall
					Calves		Weaners		Adult cows			Oxen	Bulls	
					Females	Males	Females	Males	Dry	Lactating	Pregnant			
Jan to Dec 1999	Highveld	II & III	Wedza	1 497	6.4	7.4	3.8	3.5	2.4	3.5	3.6	2.8	4.3	4.5
		II	Murewa	1 390	7.9	7.4	5.4	2.6	3.5	4.3	1.5	2.8	2.3	4.9
		II	Zvimba	842	6.5	7.6	3.9	3.8	1.5	5.7	3.0	1.1	0.0	4.4
		II	Mazowe	1 368	3.7	4.7	3.6	2.7	0.0	3.5	2.6	1.7	2.2	3.2
			Overall	5 097	6.1^{a}	6.6^{a}	4.2^{g}	3.1^{g}	2.4^{c}	4.0^{g}	2.6^{c}	2.2^{c}	2.4^{c}	4.3^{aa}
	Lowveld	IV	Zvishavane	1 354	1.7	2.3	0.8	0.9	1.4	0.8	0.0	0.0	0.0	1.1
		IV	Mberengwa	1 554	2.3	2.5	1.4	1.2	2.6	0.0	0.9	0.7	2.3	1.7
		IV	Plumtree	1 109	4.9	4.0	2.1	1.5	0.0	1.6	0.0	0.8	2.9	2.3
			Overall	4 017	3.2^{b}	2.9^{b}	1.4^{f}	1.2^{f}	1.2^{f}	0.6^{d}	0.4^{d}	0.5^{d}	1.7^{f}	1.7^{bb}
Jan to Dec 2000	Highveld	II & III	Wedza	1 624	9.5	7.7	4.7	3.6	4.8	5.6	5.8	3.9	3.1	5.7
		II	Murewa	–	–	–	–	–	–	–	–	–	–	–
		II	Zvimba	401	10.4	7.6	2.7	3.3	3.8	4.0	8.3	5.3	0.0	5.7
		II	Mazowe	1 348	15.8	12.8	8.2	8.2	11.1	5.7	6.2	5.3	7.1	9.6
			Overall	3 373	12.1^{a}	9.8^{c}	6.0^{b}	5.2^{b}	5.9^{b}	5.5^{b}	6.3^{b}	4.6^{e}	4.0^{e}	7.3^{cc}
	Lowveld	IV	Zvishavane	762	5.1	5.1	2.5	3.8	4.3	6.3	1.9	1.4	3.0	3.8
		IV	Mberengwa	1 620	6.6	8.9	4.0	2.9	4.5	3.3	3.1	4.3	3.4	4.9
		IV	Plumtree	1 395	11.0	9.3	5.5	5.8	6.0	5.0	4.9	4.3	1.6	6.8
			Overall	3 777	7.9^{d}	8.2^{d}	4.2^{g}	4.2^{g}	5.1^{g}	4.4^{g}	3.4^{f}	3.7^{f}	2.6^{c}	5.4^{aa}

Figures with a different superscript in a column or row under overall prevalence are significantly different at $P < 0.05$

*N = Total number of animals sampled

FIG. 2

Mean monthly prevalence (%) and mean monthly faecal egg counts of *Schistosoma mattheei* in cattle (A) and mean monthly rainfall and temperature (B) in the highveld and lowveld communal grazing areas of Zimbabwe for the period January 1999 to December 2000



Snail abundance and distribution

The relative abundances and distribution of snails according to region and district are shown in Table 4. A total of 2 936 *B. globosus* was collected during the entire period of the study, 2 222 from the highveld (75.7 %) and 714 from the lowveld (24.3 %). A significantly higher mean number of snails was collected from the highveld than the lowveld ($P < 0.01$). The mean number of *B. globosus* collected in Wedza (highveld) and Mberengwa (lowveld) districts showed an annual variation with higher numbers collected in the second year ($P < 0.01$) than in the first. However, for both regions, there were no significant differences in the overall mean numbers of snails collected between the 2 years.

The distribution of the snails according to habitat is shown in Table 5. No significant variation in the number of snails between dams and streams was noted

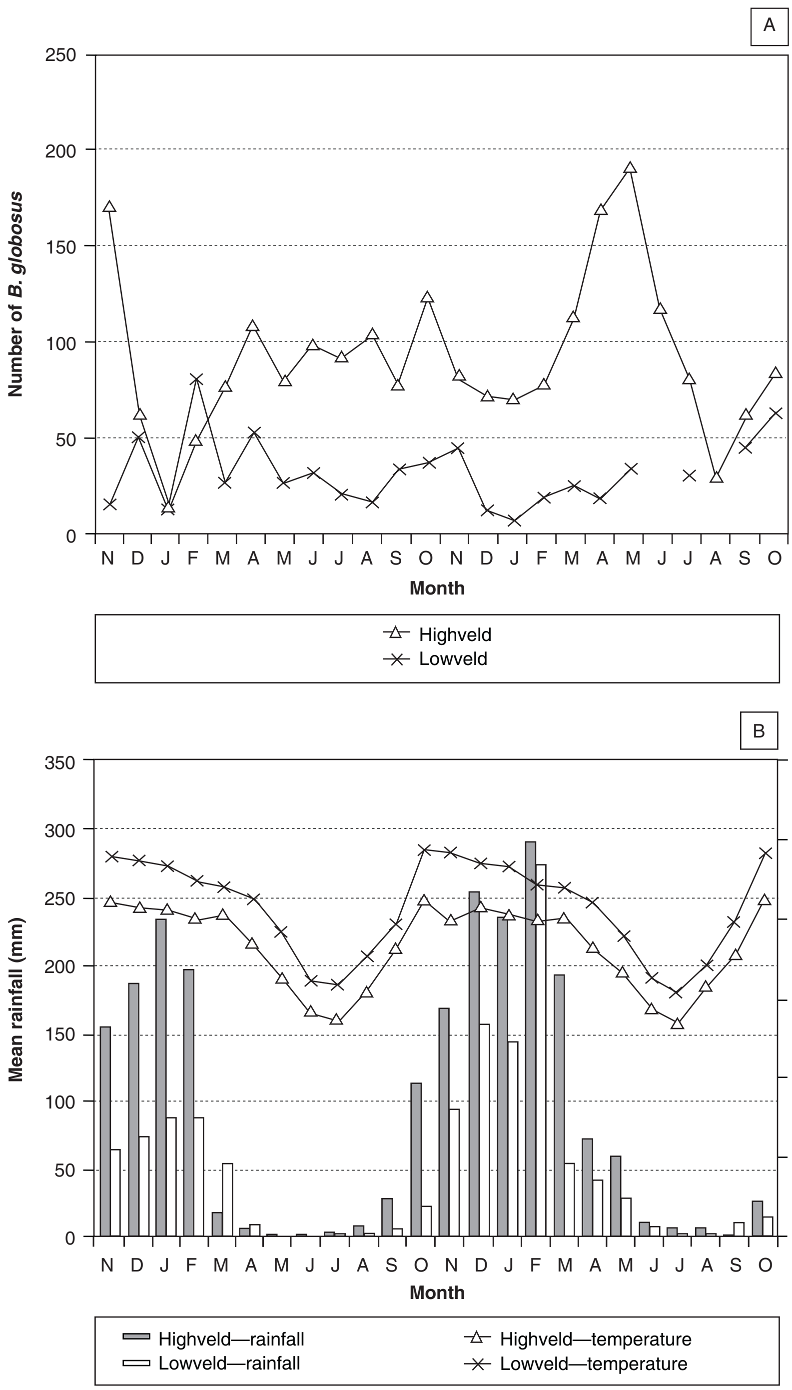


FIG. 3

Monthly variation of *Bulinus globosus* (A) and mean monthly rainfall and temperature (B) in the highveld and lowveld communal grazing areas of Zimbabwe for the period November 1998 to October 2000

in the highveld. However, significantly higher numbers of *B. globosus* were collected from highveld dams ($P < 0.01$) than lowveld dams. There was a positive correlation between the mean number of snails collected and the plants *Typha* spp. ($r = 0.64$) and *Nymphaea caerulea* ($r = 0.58$).

The seasonal distribution of *B. globosus* is shown in Table 6. In the highveld, significantly ($P < 0.01$) lower mean numbers were collected during the rainy season in Year 1 than in Year 2 and significantly ($P <$ 0.01) more snails were collected during the post-rainy season in Year 2 than in Year 1. However, in the lowveld there were no significant variations among seasons during the 2-year study period.

The monthly number of snails recorded was higher for the highveld than for the lowveld and showed no clear-cut pattern although there were peaks between March/May and September/November (Fig. 3). The

TABLE 3 Seasonal mean prevalence (%) and mean faecal egg counts of *Schistosoma mattheei* in the different age categories of cattle by region and year in the highveld and lowveld communal grazing areas of Zimbabwe as from January 1999 to December 2000

Season	Region	Age group	Year 1 (Jan to Dec 1999)			Year 2 (Jan to Dec 2000)		
			*N	Mean prevalence (%)	Mean ± SD	*N	Mean prevalence (%)	Mean ± SD
Wet	Highveld	Calves	754	9.2	54.3 ± 23.8	581	11.9	66.4 ± 12.6
		Weaners	775	4.1	26.8 ± 13.8	597	6.7	42.8 ± 8.9
		Adults	759	4.7	19.2 ± 11.9	571	11.4	24.6 ± 4.5
		Overall	2 288	6.0[a]	33.4 ± 19.9	1 749	9.9[b]	44.6 ± 9.5
	Lowveld	Calves	656	3.5	42.8 ± 42.4	604	8.1	34.6 ± 19.1
		Weaners	669	2.1	24.3 ± 12.3	594	4.9	21.4 ± 15.0
		Adults	657	1.2	18.6 ± 3.4	599	6.5	14.3 ± 15.4
		Overall	1 982	2.3[c]	28.6 ± 33.8	1 797	6.5[d]	23.4 ± 17.0
Dry	Highveld	Calves	955	3.2	22.4 ± 16.1	536	6.2	18.4 ± 11.8
		Weaners	921	3.3	16.3 ± 8.1	550	2.9	12.8 ± 6.7
		Adults	933	2.0	10.3 ± 9.2	538	4.1	6.5 ± 10.5
		Overall	2 809	2.8[c]	16.3 ± 12.5	1624	4.4[e]	12.6 ± 10.4
	Lowveld	Calves	671	1.2	3.8 ± 2.9	661	7.7	10.2 ± 15.1
		Weaners	695	0	0	659	4.2	7.6 ± 7.8
		Adults	669	0	0	660	3.5	4.5 ± 4.7
		Overall	2 035	0.4[f]	3.8 ± 2.9	1 980	5.2[g]	7.4 ± 11.7

Figures with a different superscript within a column or row under overall prevalence are significantly different at $P < 0.05$
SD = Standard deviation
*N = Total number of animals sampled

TABLE 4 Recovery of *Bulinus globosus* from seven districts in the highveld and lowveld communal grazing areas of Zimbabwe for the period November 1998 to October 2000

Region	District	No. of sites	Year 1 (Nov 1998 to Oct 1999)		Year 2 (Nov 1999 to Oct 2000)	
			Total collected	Monthly mean ± SD	Total collected	Monthly mean ± SD
Highveld	Mazowe	3	186	5.2[a] ± 7.1	205	6.2[a] ± 8.8
	Wedza	3	220	6.1[a] ± 10.3	334	10.1[b] ± 8.5
	Murewa	3	192	5.3[a] ± 16.1	191	5.3[a] ± 8.6
	Zvimba	3	468	13.0[b] ± 20.3	426	14.2[b] ± 11.0
	Overall	12	1 066	7.4[b] ± 14.6	1 156	8.8[b] ± 12.8
Lowveld	Zvishavane	3	0	0	9	0.3[c] ± 1.2
	Mberengwa	3	215	6.0[a] ± 10.1	244	8.1[b] ± 10.5
	Plumtree	3	194	5.4[a] ± 12.5	52	1.7[a] ± 7.1
	Overall	9	409	3.8[d] ± 9.6	305	3.4[d] ± 8.0

Figures with a different superscript within a column or row are significantly different at $P < 0.05$
SD = Standard deviation

TABLE 5 Recovery of *Bulinus globosus* according to habitat from seven districts in the highveld and lowveld communal grazing areas of Zimbabwe for the period November 1998 to October 2000

Region	Habitat	No. of sites	Year 1 (Nov 1998 to Oct 1999)		Year 2 (Nov 1999 to Oct 2000)	
			Total collected	Monthly mean ± SD	Total collected	Monthly mean ± SD
Highveld	Stream	6	574	8.0^{a} ± 15.3	489	7.6^{a} ± 10.5
	Dam	6	492	6.8^{a} ± 13.9	667	9.8^{a} ± 14.7
Lowveld	Dam	9	409	3.8^{b} ± 9.6	305	3.4^{b} ± 8.0

Figures with a different superscript within a column or row are significantly different at $P < 0.05$
SD = Standard deviation

TABLE 6 Seasonal distributions of *Bulinus globosus* in the highveld and lowveld communal grazing areas of Zimbabwe for the period November 1998 to October 2000

Region	Season	Year 1 (Nov 1998 to Oct 1999)		Year 2 (Nov 1999 to Oct 2000)	
		Total collected	Monthly mean ± SD	Total collected	Monthly mean ± SD
Highveld	Post-rainy (Mar to May)	268	7.4^{a} ± 12.6	475	15.8^{c} ± 18.2
	Cold-dry (Jun to Aug)	296	8.2^{a} ± 18.7	230	7.7^{a} ± 8.2
	Hot-dry (Sep to Nov)	374	10.4^{a} ± 17.5	230	6.4^{a} ± 12.2
	Rainy (Dec to Feb)	128	3.6^{b} ± 5.4	221	6.1^{a} ± 8.8
Lowveld	Post-rainy (Mar to May)	107	4.0^{d} ± 8.5	79	2.9^{d} ± 8.2
	Cold-dry (Jun to Aug)	70	2.6^{d} ± 4.9	31	3.4^{d} ± 6.7
	Hot-dry (Sep to Nov)	86	3.2^{d} ± 8.7	156	5.8^{d} ± 10.6
	Rainy (Dec to Feb)	146	5.4^{d} ± 14.2	39	1.4^{d} ± 4.1

Figures with a different superscript within a column or row are significantly different at $P < 0.05$
SD = Standard deviation

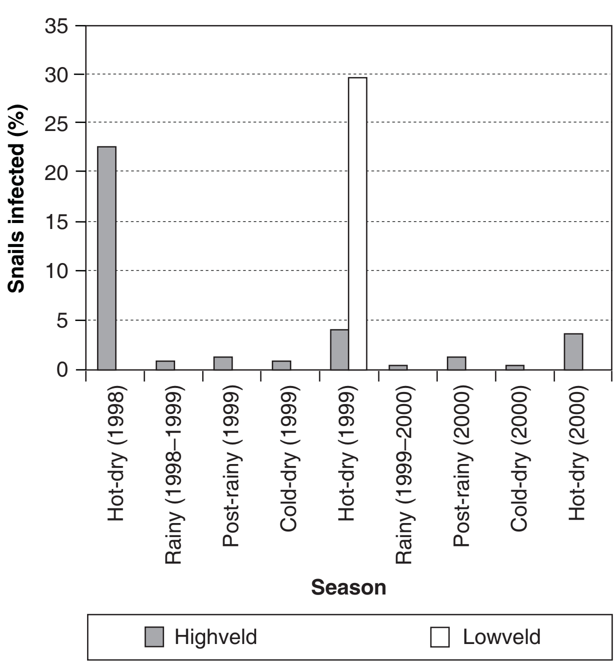


FIG. 4 Seasonal proportion (%) of *Bulinus globosus* snails infected with *Schistosoma* cercariae in the highveld and lowveld of Zimbabwe for the period November 1998 to October 2000

mean number of snails recorded was negatively correlated with rainfall ($r = -0.56$).

Overall, 2.5 % of *B. globosus* were shedding *Schistosoma* spp. cercariae with 2.8 % of *B. globosus* shedding the cercariae in the highveld (range 0–18.8 % at individual sites) compared to 1.5 % in the lowveld (range 0–4.5 %). At only one site in the lowveld, the Plumtree district (Matole dam), was *B. globosus* shedding *Schistosoma* spp. cercariae.

The shedding of *Schistosoma* spp. cercariae was significantly higher ($P < 0.01$) during the hot-dry season (September to November) than the cold-dry (June to August), post-rainy (March to May) and rainy seasons (December to February) (Fig. 4). In the highveld, shedding was observed during all the four seasons while it was only recorded during the hot-dry season of the first year (1999) in the lowveld (Fig. 4).

The population of juvenile *B. globosus* snails did not show a clear-cut pattern (Fig. 5). However, in the highveld there was a peak in April 2000 while in the lowveld there were peaks in April 1999, October/November 1999 and March/April 2000 (Fig. 5).

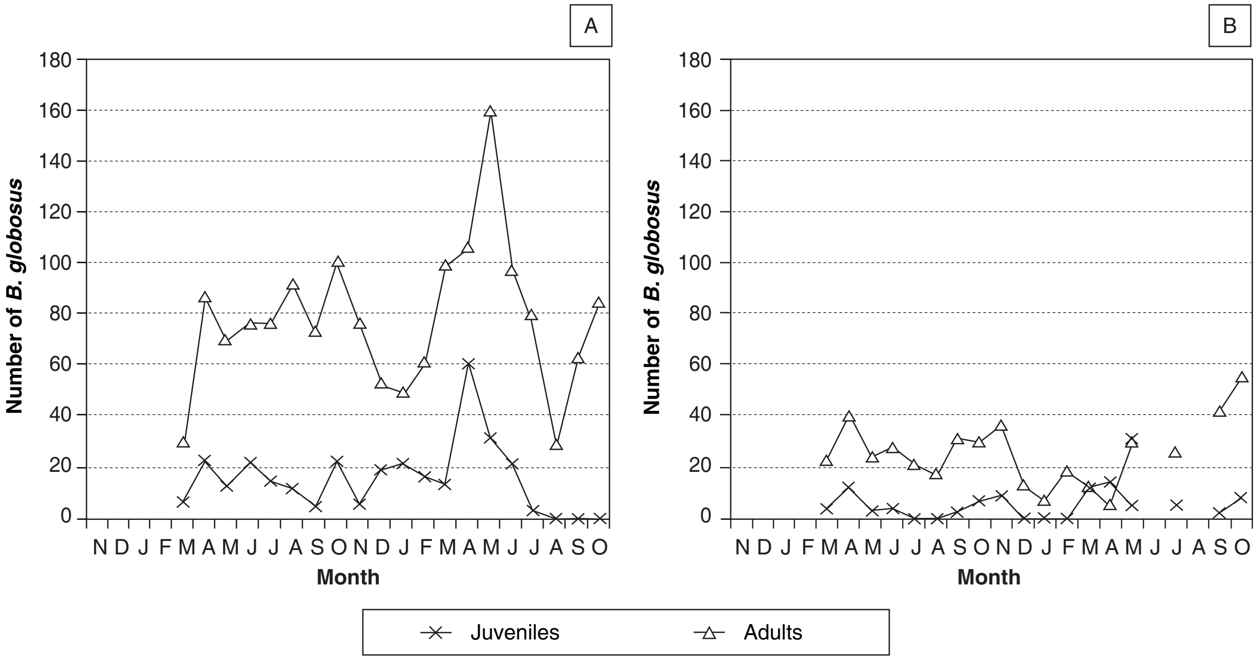


FIG. 5 Monthly variation of juvenile and adult *Bulinus globosus* snails in the highveld (A) and lowveld (B) communal grazing areas of Zimbabwe for the period November 1998 to October 2000

DISCUSSION

The overall prevalence of *S. mattheei* reported in this study agrees with that reported by Vassilev (1999) in communal farming areas of Mashonaland East Province of Zimbabwe. However, it is much lower than that reported from abattoir surveys (Condy 1960; Vercruysse, Southgate & Rollinson 1985; De Bont, Vercruysse, Southgate, Rollinson & Kaukas 1994). The low prevalence noted in this study could possibly be ascribed to limitations of the egg counting technique (De Bont, Van Lieshout, Deelder, Ysebaert & Vercruysse 1996a; De Bont & Vercruysse 1997, 1998), coupled with a low egg production due to an immunological response by the host to repeated reinfection (Lawrence 1973, 1977). From the animal health and epidemiological point of view, the fact that many adult animals with fecundity-suppressed worms are missed by faecal examination does not really have any significance since these animals are neither severely debilitated nor contributing much to transmission (De Bont & Vercruysse 1997).

Under normal endemic conditions, the faecal egg output rarely exceeds 50 epg of faeces (Majid, Marshall, Hussein, Bushara, Taylor, Nelson & Dargie 1980; Pitchford & Visser 1982; Kassuku, Christensen, Monrad, Nansen & Knudsen 1986; De Bont, Vercruysse, Sabbe, Southgate & Rollinson 1995). Animals used in this study were most likely to be continuously exposed to reinfection, and the low mean egg counts encountered in this study agrees with findings from other parts of Africa (Pitchford & Visser 1982; Kassuku *et al.* 1986). Faecal egg counts during clinical outbreaks may vary between 100 and 1 000 epg (Van Wyk, Bartsch, Van Rensburg, Heitmann & Goosen 1974; Lawrence 1978; Dargie 1980; Markovics, Perl, Orgad & Pipano 1993).

In agreement with the results of Lawrence (1978), infection with *S. mattheei* was found to be more common in the higher rainfall districts of the highveld than in the relatively drier districts of the lowveld. Lawrence (1978) also reported the highest prevalence of clinical outbreaks of schistosomosis in the north-east of the country, which falls mainly into Natural Regions II and III, with a low prevalence of schistosomosis in the remainder of the country, which has low rainfall, and a paucity of surface water. During the present study relatively high prevalences and egg counts were recorded during the dry season and this could probably be attributed to infections acquired at the end of the rainy and early dry seasons.

In the present study and studies by Pitchford & Visser (1982) and De Bont *et al.* (1995), the prevalence of *S. mattheei* in cattle as measured by faecal egg counts was higher in calves than in either the weaners or the adults. Although a decline in faecal egg counts with age may be expected in growing cattle as a result of greater egg dilution in increasing faecal masses (De Bont *et al.* 1995), it has been demonstrated experimentally (Lawrence 1973, 1977) that the time-related decline in *S. mattheei* faecal egg excretion is mainly due to an immune-mediated suppression of fluke fecundity. Similar changes have been reported in cattle infections involving other schistosome species such as *Schistosoma bovis* (Bushara, Majid, Saad, Hussein, Taylor, Dargie, Marshall & Nelson 1980; Majid *et al.* 1980) and *Schistosoma spindale* (De Bont, Vercruysse, Van Aken, Southgate, Rollinson & Moncrieff 1991).

The decline in egg output with age means that animals below 2 years of age play the most important role in the environmental contamination with eggs (De Bont & Vercruysse 1997). The potential importance of older animals in the spread of schistosomosis is further reduced by an age-related decrease in egg hatchability. In Sri Lanka, the faecal excretion of viable eggs by *S. spindale* was highest (96 miracidia per 100 g) in animals of 2 years and younger, thereafter decreasing with age to 11 miracidia per 100 g in cattle of 3 years and older (De Bont *et al.* 1991). In Zambia, 50 % of the eggs of *S. mattheei* from calves hatched in water, compared with only 15 % of eggs from adult cows (De Bont, Vercruysse & Massuku 1996b). The findings of this present study support the notion that young animals play an important role in the contamination of the environment with eggs.

The intermediate snail host, *B. globosus*, thrives in various water bodies including streams, rivers, seasonal pools, lakes, earth dams and irrigation systems and it excels at exploiting the small seasonal water bodies that are the only kind of habitat in large areas of Africa (Brown 1994). Thus, the highveld, with a wider distribution of permanent rivers, seasonal streams and pools provides more suitable habitats for the snail intermediate hosts than the lowveld. The results of this present study showed a significantly higher abundance of *B. globosus* from districts in the highveld than those in the lowveld and this might explain the difference observed in the prevalence of *S. mattheei* in cattle between the two types of veld.

Bulinus globosus has been reported to be associated with the presence of aquatic plants like *Cyperus* spp., *Typha latifolia* and *Potamogeton thunbergii* in Zimbabwe (Woolhouse & Chandiwana 1989). In the present study, numbers of *B. globosus* were also found to be correlated with another *Typha* spp., as well as with *N. caerulea*, and these plant species may thus be regarded as useful indicators of *B. globosus* abundance in the regions studied.

Although the snail hosts of schistosomes tolerate a wide range of environmental conditions, their local distribution has been found to be patchy, with aggregations along short distances on the banks of a lake or stream (Brown 1994). In the highveld of Zimbabwe differences between sites in peak of absolute density and recruitment rates of *B. globosus* have been demonstrated by Woolhouse & Chandiwana (1989, 1990a) and the prevalence of patent infections in the snails varied from 0–70 % over distances of less than 100 m (Woolhouse & Chandiwana 1990b). In the present study, both the occurrence of schistosomes and the relative abundance of the snail intermediate host varied among sites within the same district. Such differences have been attributed to recent history of river conditions, i.e. floods and drought, and patchy contamination of the water by excreta (Woolhouse & Chandiwana 1989; 1990b).

Studies by Shiff *et al.* (1979) and Chandiwana *et al.* (1987) indicated that the transmission of both *S. haematobium* and *S. mattheei* in the highveld region of Zimbabwe is seasonal similar to that found with the snails in this study. The epidemiological patterns observed during the present study would probably be confounded by the presence of the human schistosome as no effort was made to differentiate between *S. haematobium* and *S. mattheei* cercariae. However, a 3-year survey conducted in the highveld region, between September 1974 and October 1977, showed that 80 % (28/35) of the infections in *B. globosus* during the cold dry season were due to *S. mattheei* (Shiff *et al.* 1979).

Studies have shown that the prepatent period for *S. mattheei* is usually 6–7 weeks (Lawrence 1977). The findings of peak faecal egg counts in cattle from October/November to March/April suggest that high exposure to the infective stages occurred from around August/September, through to March. This pattern of transmission, therefore, would explain the high faecal egg count seen in this study during the wet season. Similar patterns of transmission have been observed in South Africa (Pitchford & Visser 1965; 1966; Pitchford, Meyling, Meyling & Du Toit 1969) and Zambia (De Bont *et al.* 1995).

ACKNOWLEDGEMENTS

We thank the Danish International Development Agency (DANIDA) as part of the ENRECA Livestock Helminths Research Project who wholly sponsored these studies. Thanks are also due to laboratory staff of the Parasitology Section, Department of Paraclinical Veterinary Studies and the Central Veterinary

Laboratory for their able assistance with the helminthological work. The Department of Meteorology, Belvedere, Harare is thanked for kindly providing climatic data of the studied districts.

REFERENCES

BORAY, J.C. & PEARSON, I.G. 1960. The anthelmintic efficiency of tetrachloro-difluoroethane in sheep infested with *Fasciola hepatica*. *Australian Veterinary Journal*, 36:331–337.

BROWN, D.S. & KRISTENSEN, T.K. 1989. A field guide to African freshwater snails, southern African species. Danish Bilharziasis Laboratory, Publication no. 383.

BROWN, D. 1994. *Freshwater snails of Africa and their medical Importance*, 2nd ed. Department of Zoology, Natural History Museum. London: Taylor & Francis Ltd.

BUSHARA, H.O., MAJID, A.A., SAAD, A.M., HUSSEIN, M.F., TAYLOR, M.G., DARGIE, J.D., MARSHALL, T.F. DE C. & NELSON, G.S. 1980. Observations on cattle schistosomiasis in the Sudan, a study in comparative medicine. II. Experimental demonstration of naturally acquired resistance to *Schistosoma bovis. American Journal of Tropical Medicine and Hygiene*, 29:442–451.

CHANDIWANA, S.K., CHRISTENSEN, N.Ø. & FRANDSEN, F. 1987. Seasonal patterns in the transmission of *Schistosoma haematobium, S. mattheei* and *S. mansoni* in the highveld region of Zimbabwe. *Acta Tropica*, 44:433–444.

CONDY, J.B. 1960. Bovine schistosomiasis in Southern Rhodesia. *Central African Journal of Medicine*, 6:381–384.

COULIBALY, G. & MADSEN, H. 1990. Seasonal fluctuations of intermediate hosts of schistosomes in two streams in Bamako, Mali. *Journal of African Zoology*, 104:201–212.

DARGIE, J.D. 1980. The pathogenesis of *Schistosoma bovis* infection in Sudanese cattle. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 74:560–562.

DE BONT, J., VERCRUYSSE, J., VAN AKEN, D., SOUTHGATE, V.R., ROLLINSON, D. & MONCRIEFF, C. 1991. The epidemiology of *Schistosoma spindale* Montgomery, 1906, in cattle in Sri Lanka. *Parasitology*, 102:237–241.

DE BONT, J., VERCRUYSSE, J., SOUTHGATE, V.R., ROLLINSON, D. & KAUKAS, A. 1994. Cattle schistosomiasis in Zambia. *Journal of Helminthology*, 68:295–299.

DE BONT, J., VERCRUYSSE, J., SABBE, F., SOUTHGATE, V. R. & ROLLINSON, D. 1995. *Schistosoma mattheei* infections in cattle: changes associated with season and age. *Veterinary Parasitology*, 57:299–307.

DE BONT, J., VAN LIESHOUT, L., DEELDER, A.M., YSEBAERT, M.T. & VERCRUYSSE, J. 1996a. Circulating antigen levels in serum of cattle naturally infected with *Schistosoma mattheei. Parasitology*, 113:465–471.

DE BONT, J., VERCRUYSSE, J. & MASSUKU, M. 1996b. Variations in *Schistosoma mattheei* egg morphology and viability according to age of infection in cattle. *Journal of Helminthology*, 70:265–267.

DE BONT, J. & VERCRUYSSE, J. 1997. The epidemiology and control of cattle schistosomiasis. *Parasitology Today*, 13:255–262.

DE BONT, J. & VERCRUYSSE, J. 1998. Schistosomiasis in cattle. *Advances in Parasitology*, 41:285–364.

FRANDSEN, F. & CHRISTENSEN, M.O. 1984. An introductory guide to the identification of cercariae from African freshwater snails with special reference to cercariae of trematode species of medical and veterinary importance. *Acta Tropica*, 41:181–202.

KASSUKU, A.A., CHRISTENSEN, N.Ø., MONRAD, J., NANSEN, P. & KNUDSEN, J. 1986. Epidemiological studies on *Schistosoma bovis* in Iringa Region, Tanzania. *Acta Tropica*, 43:153–163.

LAWRENCE, J.A. 1973. *Schistosoma mattheei* in cattle: the host-parasite relationship. *Research in Veterinary Science*, 14:400–402.

LAWRENCE, J.A. 1977. *Schistosoma mattheei* in the ox: observations on the parasite. *Veterinary Parasitology*, 3:291–303.

LAWRENCE, J.A. 1978. Bovine schistosomiasis in Southern Africa. *Helminthological Abstracts Series A, Animal and Human Helminthology*, 47:261–270.

MAJID, A.A., MARSHALL, T.F. DE C., HUSSEIN, M.F., BUSHARA, H.O., TAYLOR, M.G., NELSON, G.S. & DARGIE, J.D. 1980. Observations on cattle schistosomiasis in the Sudan, a study in comparative medicine. I. Epizootiological observations on *Schistosoma bovis* in the White Nile Province. *American Journal of Tropical Medicine and Hygiene*, 29:435–441.

MAKURA, O. & KRISTENSEN, T.K. 1991. National freshwater survey of Zimbabwe. *Proceedings of the Tenth International Malacology Congress (Tubingen)*: 227–232.

MARGOLIS, L., ESCH, G.W., HOLMES, J.C., KURIS, A.M. & SCHAD, G.A. 1982. The use of ecological terms in parasitology, Report on an *ad hoc* committee of the American Society of Parasitologists. *Journal of Parasitology*, 68:131–133.

MARKOVICS, A., PERL, S., ORGAD, U. & PIPANO, E. 1993. Outbreaks of schistosomiasis (*Schistosoma bovis*) in cattle and sheep. *Israel Journal of Veterinary Medicine*, 48:123–125.

MUKARATIRWA, S. & KRISTENSEN, T.K. 1995. A review on status of vector snails of urinary schistosomiasis in Zimbabwe, in *Proceedings of "A status of research on medical malacology in relation to schistosomiasis in Africa"*, edited by H. Madsen, T.K. Kristensen & P. Ndhlovu. Danish Bilharziasis Laboratory and Blair Research Institute Charlottenlund, Denmark/Harare, Zimbabwe.

PITCHFORD, R.J. & VISSER, P.S. 1965. Some further observations on schistosome transmission in the Eastern Transvaal. *Bulletin of the World Health Organization*, 32:83–104.

PITCHFORD, R.J. & VISSER, P.S. 1966. The activity of various schistosome cercariae in outdoor aquaria. *Annals of Tropical Medicine and Parasitology*, 60:518–521.

PITCHFORD, R.J., MEYLING, A.H., MEYLING, J. & DU TOIT, J.F. 1969. Cercarial shedding patterns of various schistosome species under outdoor conditions in the Transvaal. *Annals of Tropical Medicine and Parasitology*, 63:359–371.

PITCHFORD, R.J. & VISSER, P.S. 1982. *Schistosoma mattheei* Veglia & Le Roux, 1929 egg output from cattle in a highly endemic area in the Eastern Transvaal. *Onderstepoort Journal of Veterinary Research*, 49:233–235.

SHIFF, C.J., COUTTS, W.C.C., YIANNAKIS, C. & HOLMES, R. W. 1979. Seasonal patterns in the transmission of *Schistosoma haematobium* in Rhodesia, and its control by winter application of molluscicide. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 73:375–380.

VAN WYK, J.A., BARTSCH, R.C., VAN RENSBURG, L.J., HEITMANN, L.P. & GOOSEN, P.J. 1974. Studies on schistosomiasis. VI. A field outbreak of bilharzia in cattle. *Onderstepoort Journal of Veterinary Research*, 41:39–49.

VASSILEV, G.D. 1994. Prevalence and seasonality of internal parasite infections detectable by faecal examination of cattle in Chiweshe communal farming area of Zimbabwe. *Zimbabwe Veterinary Journal*, 25:41–63.

VASSILEV, G.D. 1999. Prevalence of internal parasite infections of cattle in the communal farming areas of Mashonaland East Province, Zimbabwe. *Zimbabwe Veterinary Journal*, 30:1–17.

VERCRUYSSE, J., SOUTHGATE, V.R. & ROLLINSON, D. 1985. The epidemiology of human and animal schistosomiasis in the Senegal River Basin. *Acta Tropica*, 42:249–259.

WOOLHOUSE, M.E.J. & CHANDIWANA, S.K. 1989. Spatial and temporal heterogeneity in the population dynamics of *Bulinus globosus* and *Biomphalaria pfeifferi* and in the epidemiology of their infection with schistosomes. *Parasitology*, 98:21–34.

WOOLHOUSE, M.E.J. & CHANDIWANA, S.K. 1990a. Population biology of the freshwater snail *Bulinus globosus* in the Zimbabwe highveld. *Journal of Applied Ecology*, 27:41–59.

WOOLHOUSE, M.E.J. & CHANDIWANA, S.K. 1990b. The epidemiology of schistosome infections of snails: taking the theory into the field. *Parasitology Today*, 6:65–70.